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(56) Publications used in assessing patentability:

M. Heiss, *Pulsanzahlmodulator*…., in: at—Automatisierungstechnik 41 (1993), 11, pp. 428-432;

(54) Electrical Circuit Arrangement

(57) A proposed electrical circuit arrangement is essentially made up of a microprocessor to whose pulse-width-modulated processor output a low-pass filter made up of a resistor and a capacitor is connected in order to generate a plurality of stably settable voltages. For the purpose of creating a circuit arrangement with which the various analog voltages can be set within a very short span of time in a clean and smoothed form, there is an additional resistor, substantially smaller in value than the resistor, which additional resistor is connected on the one hand to the low-pass filter output and on the other to a processor port that can be alternatively switched to be input or output, the additional resistor being connected to the processor operating voltage via the processor port switched to be output for a well-defined time interval in order to set a higher voltage level and being connected to ground for a well-defined time interval in order to set a lower voltage level, the processor port being switched back to be input when the voltage level to be set has been attained, so that the additional resistor becomes or remains without effect during the holding of the voltage level.

Specification

This invention departs from an electrical circuit arrangement according to the preamble of the principal Claim: *at—Automatisierungstechnik* 41 (1993) 11, pp. 428-432.

Such electrical circuit arrangements are provided in order to set the analog voltage supplied to a consumer or respectively a consumer circuit to a certain voltage level.

It is generally known to employ a pulse-width-modulated processor output of a microprocessor as well as a subsequently connected low-pass filter in order to set an analog voltage. A pulse-width-modulated signal having a certain pulse-width ratio is set at the processor output through a software setting of the microprocessor. In this way, in dependence on the operating voltage present and the pulse-width ratio present, a corresponding analog voltage is set at the low-pass filter output. The analog voltage can be varied as necessary through corresponding changes in the pulse-width-modulated signal between 0 volts and the processor operating voltage.

The time interval from the switching of the processor output to the time at which the desired analog voltage is actually set at the low-pass filter output is determined by the time constant of the low-pass filter. In order to get a stable—that is to say, clean and smoothed—analog voltage necessary in many applications, the time constant of the low-pass filter must be substantially longer than the period of the pulse-width-modulated signal. For this reason, a comparatively high-value resistor (for example 100 kΩ) in combination with a comparatively low-value capacitor (for example 100 nF[1]) is commonly selected for the realization of a low-pass filter when the period is, say, 1 msec. If various analog voltages are to be set one after another, the succession rate at which the various analog voltages can be set one after another depends on the relatively long time constant of the low-pass filter (10 msec in the example cited). This means that, in such a fashioning of electrical circuit arrangements, the number of possible switching events within a certain time interval is relatively small because of the long time constant of the low-pass filter. Thus for example only one or a small number of switching events can be effected with a pulse-width-modulated processor output of a microprocessor during one processor main loop of, say, 50 msec. With complex devices, however, the realization of the various functions requires that a large number of distinct analog voltages be rapidly set one after another within a very short time interval, for example during one processor main loop.

It is therefore an object of the invention to create an electrical circuit arrangement by which various analog voltages can be set in clean and smoothed form within a substantially shortened time interval.

According to the invention, this object is achieved with the features cited in the characterizing part of the principal Claim.

Especially advantageous in such a structure of an electrical circuit arrangement is that a plurality of

[1] Translator's Note: The symbol *nE* in the original text (column 1 line 38) is clearly an error for *nF*, the symbol correctly used elsewhere in the text.

consumers or consumer circuits can be connected to just one pulse-width-modulated processor output, the expense in terms of circuitry necessary to this end being very slight.

Further especially favorable developments are cited in the dependent Claims and are explained in greater detail with reference to exemplary embodiments illustrated in the Drawings, in which

Figure 1 shows a functional principle;

Figure 2 shows a voltage versus time diagram referred to a setting process;

Figure 3 shows a first application circuit having a consumer circuit containing a transmitter-receiver unit;

Figure 4 shows a second application circuit having two consumer circuits each containing a transmitter-receiver unit.

As follows from the Drawings, the electrical circuit implementing the functional principle is essentially made up of a microprocessor μC to whose pulse-width-modulated processor output PWM a low-pass filter made up of a resistor 1 and a capacitor 2 is connected and to whose processor port P1 an additional resistor 3 is connected on the one hand, the additional resistor being connected on the other hand to low-pass filter output TA.

In order to get a stable—that is to say, clean and smoothed—analog voltage at low-pass filter output TA, resistor 1 exhibits a resistance value of approximately 100 kΩ and capacitor 2 exhibits a capacitance of approximately 100 nF. This relationship yields a certain time constant τ for the low-pass filter that is substantially longer than the period of the pulse-width-modulated signal present at processor output PWM. Low-pass filter time constant τ determines the time interval until the voltage to be set is also actually present at low-pass filter output TA (approximately $5 \times \tau$). In order to keep this transient time interval as short as possible, an additional resistor 3 having a substantially lower resistance value of approximately 4.7 kΩ is present. This additional resistor 3 is connected on the one hand to low-pass filter output TA and on the other to a processor port P1 that can be alternatively switched to be input or output. Starting from a certain voltage level, in order to set a higher voltage level quickly, processor port P1 is switched over from the input state (high-impedance) to the output state, additional resistor 3 being connected to plus Vcc for a well-defined time interval in order to charge capacitor 2 rapidly. Once the voltage level to be set has been attained, processor port P1 is again switched to be input (high-impedance), so that additional resistor 3 ceases to have any effect and the voltage set is present in stable form at low-pass filter output TA.

A similar process results if, starting from a certain voltage level, a lower voltage level is to be set. Again, processor port P1 is first switched over from the input state (high-impedance) to the output state, but then additional resistor 3 is connected to ground for a well-defined time interval for the rapid discharging of capacitor 2. Once the voltage level to be set has been attained, here again processor port P1 is again switched to be input (high-impedance), so that additional resistor 3 ceases to have any effect and the voltage set is present in stable form at low-pass filter output TA.

Because additional resistor 3 is fashioned substantially smaller in value than

resistor 1, during the time when additional resistor 3 is switched so as to have effect, capacitor 2 is charged or discharged substantially more quickly than is commonly possible in circuit arrangements without additional resistor 3. Because, furthermore, additional resistor 3 is switched so as to have effect only for a well-defined, closely limited time interval, a set voltage is present in stable form at low-pass filter output TA despite the fast charging or discharging characteristic. The well-defined time interval in which additional resistor 3 is switched so as to have effect depends here on the voltage difference between the voltage level present and the voltage level to be set. Because of these advantageous features, such a circuit arrangement can be used for example in motor vehicle circuit devices having a complex structure and performing a multiplicity of functions.

As follows especially from Figure 2, the time interval until the voltage to be set is actually present at low-pass filter output TA is shortened by roughly a factor of 10 in comparison to a comparable circuit arrangement without corresponding additional resistor 3. The heavy continuous line in the diagram represents in idealized form the setting process for a circuit arrangement with additional resistor 3, while the dashed line represents the setting process for a circuit arrangement without additional resistor 3. The horizontal light solid line represents the voltage level present, while the horizontal dotted line represents the voltage level to be set.

Figure 3 and Figure 4 each show application circuits that include an electrical circuit part exhibiting the functional principle described. Here transmitter and receiver units fashioned as light barriers having at least one transmitter and two receivers are used. The transmitters are fashioned as infrared light-emitting diodes 4 and the receivers as infrared phototransistors 5. By way of example for the better explanation of the mode of functioning, transmitter-receiver units each having one transmitter and two or three receivers are depicted. Of course, however, a transmitter-receiver unit can be made up not only of one transmitter and a plurality of receivers but also of a plurality of transmitters and at least one receiver.

The background of the two application circuits depicted is the use of light barriers in which not only must two switching states such as for example on and off be established. These are, instead, light barriers with which various switching states, for example of a partially transparent mask, or a defect are to be reliably detected by interpretation of the analog voltage instantaneously present at receiver output EA. Because of the substantial copy control[2] of such electrooptic transmitter or receiver components, a voltage setting must be done for each individual transmitter-receiver path so that comparable and thus interpretable voltages will be obtained at receiver outputs EA.

As follows especially from Figure 3, an infrared light-emitting diode 4 is connected to low-pass filter output TA of the circuit part in question (low-pass filter with additional resistor 3), which was described above. Assigned to infrared light-emitting diode 4 are three infrared phototransistors 5, so that there are three transmitter-receiver

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[2] Translator's Note: The unknown expression *Exemplarsteuerung* in the original text (column 3 line 58) would have some such meaning as "copy control"; I suggest it is an error for *Exemplarstreuung* with the meaning "unit-to-unit variance."

paths. A certain analog voltage is set at receiver output EA of each of the three infrared phototransistors 5 in dependence on the received light intensity (light level). In order to realize a plurality of distinct switching states, a partly transparent mask situated for example between infrared light-emitting diode 4 and the three infrared phototransistors 5 is placed in various positions. A plurality, for example three, of distinct light levels can be generated through various gradations of the partial transparency of such a mask. With such a mask, a plurality of distinct light levels can thus be set for each of the three transmitter-receiver paths. Each light level combination is assigned to a certain switching function, so that a multiplicity of distinct switching functions can be represented. If a light level cannot be established by any of the three infrared phototransistors 5, there is a defect in infrared light-emitting diode 4; if, in contrast, a light level cannot be established by only one infrared phototransistor 5, this phototransistor is defective. In order to establish the various switching functions or a defect, each of infrared phototransistors 5 is connected to microprocessor μC via a further input ADW. Here, finally, the incoming analog voltage is transformed into digital signals for interpretation.

In order to set the three transmitter-receiver paths to a common starting basis from the outset, that is in particular to compensate the copy control,[3] the "first operation" is preceded by a step with an open or well-defined mask position in order to determine with what distinct voltage levels infrared light-emitting diode 4 must be operated so that the same analog voltage is set at the three receiver outputs EA of the respective infrared phototransistors 5. These three voltage levels determined must then be set one after another in "normal" operation of the electrical circuit arrangement. The setting of the voltage levels determined must take place during a very short time interval in many applications, that is, during one processor main loop. In this short time interval, the voltage level associated with infrared phototransistor 5 currently being interrogated is then set briefly, one after another, for infrared light-emitting diode 4. This is reliably and rapidly realized with the circuit part already mentioned (low-pass filter with additional resistor 3).

As follows especially from Figure 4, a plurality of consumer circuits can also be connected to a single pulse-width-modulated processor output PWM on the basis of the circuit part (low-pass filter with additional resistor 3) permitting an especially rapid setting of distinct voltage levels. In the exemplary embodiment, the first consumer current exhibits one infrared light-emitting diode 4 and two infrared phototransistors 5 and the second consumer circuit exhibits one infrared light-emitting diode 4 and three infrared phototransistors 5. In all, there are thus five individual transmitter-receiver paths fashioned as light barriers. Via the circuit part mentioned (low-pass filter with additional resistor 3), five various voltage levels are thus set one after another in a very short time interval—during one processor main loop. Because there are two consumer circuits each with one infrared light-emitting diode 4, undesired interactions can occur as a result of scattered light of the two infrared light-emitting diodes 4 if the spatial configuration is tight.

[3] Translator's Note: *Exemplarsteuerung* occurs again in the original text (column 4 line 30).

In order to eliminate such effects if there is no mechanical shading of the two infrared light-emitting diodes 4, a transistor 6 is assigned to each of the two consumer circuits. Under control of microprocessor μC via the two transistors 6, the infrared light-emitting diode 4 that is not needed at the moment is turned off. For this purpose, the two transistors 6 are connected to an additional processor output P2, P3 and the base of the control transistor of the associated infrared light-emitting diode 4. What was previously said for the exemplary embodiment of Figure 3 holds in all other points.

Claims

1. An electrical circuit arrangement having a microprocessor connected to a direct-current voltage source, to whose pulse-width-modulated processor output a low-pass filter made up of a resistor and a capacitor is connected in order to generate a settable analog voltage, characterized in that there is an additional resistor (3) substantially lower in value than the resistor (1), which additional resistor is connected on the one hand to the low-pass filter output (TA) and on the other to a processor port (P1) that can be alternatively switched to be input or output, the additional resistor (3) being connected to the processor operating voltage (Vcc) via the processor port (P1) switched to be output for a well-defined time interval in order to set a higher voltage level and being connected to ground (—) via the processor port (P1) switched to be output for a well-defined time interval in order to set a lower voltage level, and in that the processor port (P1) is switched back to be input (high-impedance) once the voltage level to be set has been attained, so that the additional resistor (3) becomes or remains without effect during the holding of the voltage level.

2. The electrical circuit arrangement of Claim 1 characterized in that the additional resistor (3) exhibits a resistance value a factor of 10 to 20 smaller than the resistor (1).

3. The electrical circuit arrangement according to Claim 1 and Claim 2 characterized in that the resistor (1) exhibits a resistance value of approximately 100 kΩ and the additional resistor (3) exhibits a resistance value of approximately 5 kΩ.

4. The electrical circuit arrangement of one of Claims 1 to 3 characterized in that the capacitor (2) cooperating with the resistor (1) and the additional resistor (3) exhibits a value of approximately 100 nF.

Attached: 3 page(s) of Drawings

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[Header on Drawing pages—the page number varies:]

[In the Drawings:]

Volt at TA

Volts at TA